A Design Model for the Digital Array Scanned Interferometer

Stephen E. Dunagan, Philip D. Hammer

An instrument model has been developed for the digital array scanned interferometer (DASI) sensor. This model predicts instrument performance in the context of specific measurement applications, and may be used to evaluate the instrument for a range of potential missions. The model may also be used to tune a design to meet specific measurement requirements, and it provides the foundation for onboard adaptation of the sensor for mission-specific measurements in a "smart-sensor" environment.

The DASI instrument is capable of acquiring remotely sensed imagery with (dimensionless) resolving power in the range of 10 to 1000. A DASI is remarkable for its compact optical design and robust mechanical configuration. In contrast with more conventional grating and prism imaging spectrometers, the most important distinguishing characteristic is that spectral resolving power is not directly dependent on the input slit aperture width, permitting very high optical throughput for carefully designed systems. The type of DASI discussed here operates in "pushbroom" mode, relying on spacecraft or aircraft motion to sweep out the along-track spatial dimension of a remotely sensed image. The sensor comprises an objective, input slit aperture, collimated interferometer section, imaging optic, and focal plane arrays (FPA). The interferometer section relies on polarization optics, a bi-refringent Wollaston prism, and an anamorphic optical component to create an interferogram across the along-track dimension of the FPA, which is a real-time analog to the scanned output of a Michelson interferometer.

The instrument model incorporates ideal optics relations for predicting imaging and magnification for the objective, collimating, cylindrical, and focusing lenses. The equations that comprise the model permit calculation of the along-track instantaneous field of view as a function of input slit aperture width, and also the straightforward cross-track angular resolution and swath angular width. The along-track spatial resolution is degraded by motion of the spacecraft (aircraft) during the frame integration time of the array detector, resulting in an elongated effective along-track angular resolution.

Detailed modeling of interferometric phenomena within the sensor and translating this information to spectral resolution and bandwidth specifications is more complex. Spectral resolution is a function of the maximum path difference. (This statement is also true for a grating spectrometer, because it is the number of grooves that gives the theoretical resolving power. The product of the number of grooves and grating groove spacing is the grating width, or path difference over which beams interfere to yield the spectrum). The limiting effective aperture for a well-designed DASI system is the width of the detector array, which may be related to an effective aperture in the Wollaston by means of the magnifications associated with the imaging lens and (anamorphic) cylinder lens. These dimensions permit the calculation of a maximum wave number resolution and corresponding wavelength resolution.

Other important modeling considerations include the evaluation of clear aperture requirements within the instrument, and the effect of real optics on the interference and imaging functions of the sensor. Vignetting of the interferogram (in one or both dimensions of the array) is minimized by proper optical design choices. The amplitude effects of vignetting can be accounted for during calibration. However, the signal-to-noise ratio (SNR) suffers as detected flux decreases because of vignetting and/or cosine effects related to the large field of view the DASI achieves in the spatial dimension. The projection of the array width to the plane of fringe localization within the Wollaston is a good indicator of the along-track clear aperture requirement for the collimated section.

The cross-track (y) dimension is subject to other constraints. The effective slit length requirement based on utilization of the entire array detector may be calculated from the projection of the array length to the slit. Nearly parallel skew rays entering the system from the periphery of object space (located near infinity) are focused by the objective lens to the edge of the slit. Rays from the aperture edges of the objective lens must traverse the entire interferometer without clipping in order to avoid vignetting effects that precipitate undesirable loss of intensity (and SNR) at the edges of the FPA. The refraction of rays in the zero-power polarizer, Wollaston prism, and cylindrical lens elements in the collimated section of the interferometer may be estimated by evoking a $\sin(u) \cong \tan(u)$ approximation. This analysis draws attention to the need for very fast collimating and imaging lenses. Alternatively, the instrument field of view (limited by the combination of objective focal length and slit length) and light gathering capability (limited by the f-ratio of the objective) may be reduced to meet the practical aperture limitations placed on the imaging lens.

This model has been formalized in concise mathematical form and prepared for publication. Ongoing work is directed at the development of model elements for two additional instrument characteristics that are very important for matching an instrument design to a particular application. These include the modeling of instrument throughput, including SNR as a function of spectral reflectance and atmospheric conditions, and the instrument lineshape. Work is also under way on a ray-tracing model for generalized two-beam interferometric instruments that will enable the formulation of more advanced designs and the realization of the full potential of DASI-type instruments. William H. Smith (Department of Earth and Planetary Sciences, Washington University) collaborated in this work.

Point of Contact: S. Dunagan
(650) 604-4560
sdunagan@mail.arc.nasa.gov

Fires, Floods, and Deforestation—Disaster Management Using Remote Sensing Technology

James A. Brass, Vincent Ambrosia, Robert Higgins

Worldwide, 70 major disasters requiring international assistance occur each year. These disasters result in 133,000 deaths, 140 million homeless, and $440 billion in property damage. In the last decade, U.S. property loss has averaged $54 billion per year. Obviously, disasters are expensive to manage and they result in destruction to homes and businesses, and loss of commerce and lives.

Through NASA's Office of Earth Science Natural Hazards Program, technology is being developed and tested to support the management mitigation of natural and man-made disasters. In cooperation with the U.S. Forest Service Riverside Fire Laboratory, an aircraft system has been developed to collect visible, infrared, and thermal data for disaster characterization and monitoring. The digital data are compressed onboard the aircraft and sent to the Internet for data distribution and information extraction.

Two major efforts were completed in FY99. The U.S./Brazil Global Change and Environmental Monitoring Program was continued to characterize fire effects and deforestation on the rainforest and savanna ecosystem of northern Brazil. This effort resulted in describing the variation in fire types throughout both ecosystems; differing fire intensities and duration will result in variation in nutrient movement, greenhouse gas generation, and plant succession. In addition, the relationship between deforestation and fire occurrence was examined to determine the role of fire in deforestation activities.

Gigabytes of image data were collected over the northern part of Brazil. Preliminary results indicate a large variability between fires and within fires (often flame temperatures range between 600 degrees Centigrade (°C) and 1000°C). In addition, fire characteristics such as the duration of smoldering and flaming activity within fires were extremely variable, resulting in different trace-gas species and amounts being produced by the fires.

The second major effort in FY99 was the demonstration and operational use of remote sensing for fire management. The Airborne Infrared Disaster